National Aeronautics and Space Administration

TAMEST O'Donnell Award

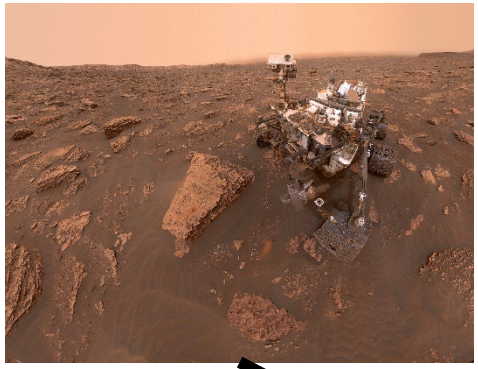
Remotely Operating Robots for Space Exploration

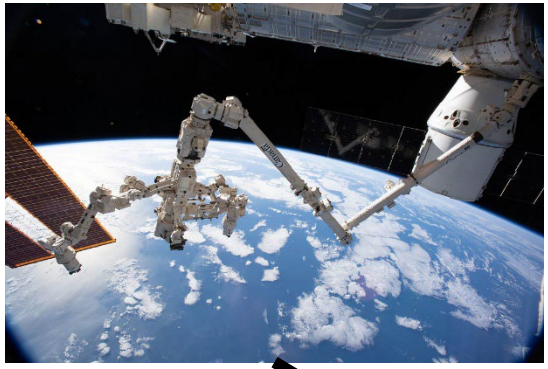
Dr. Kimberly Hambuchen

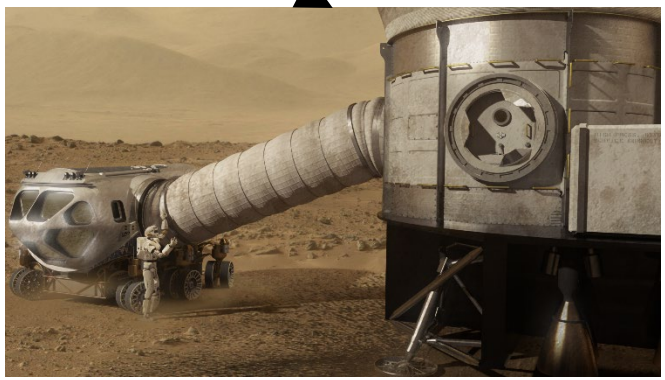
February 7, 2024

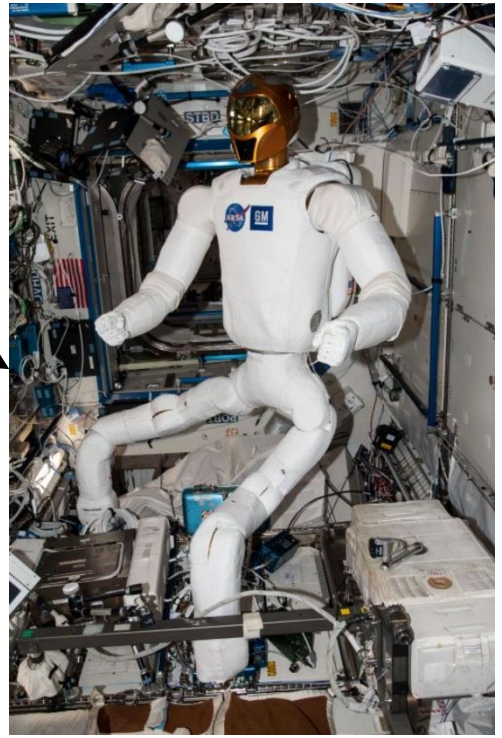
Career Focus

- How will NASA operate complex robots for future space exploration missions?

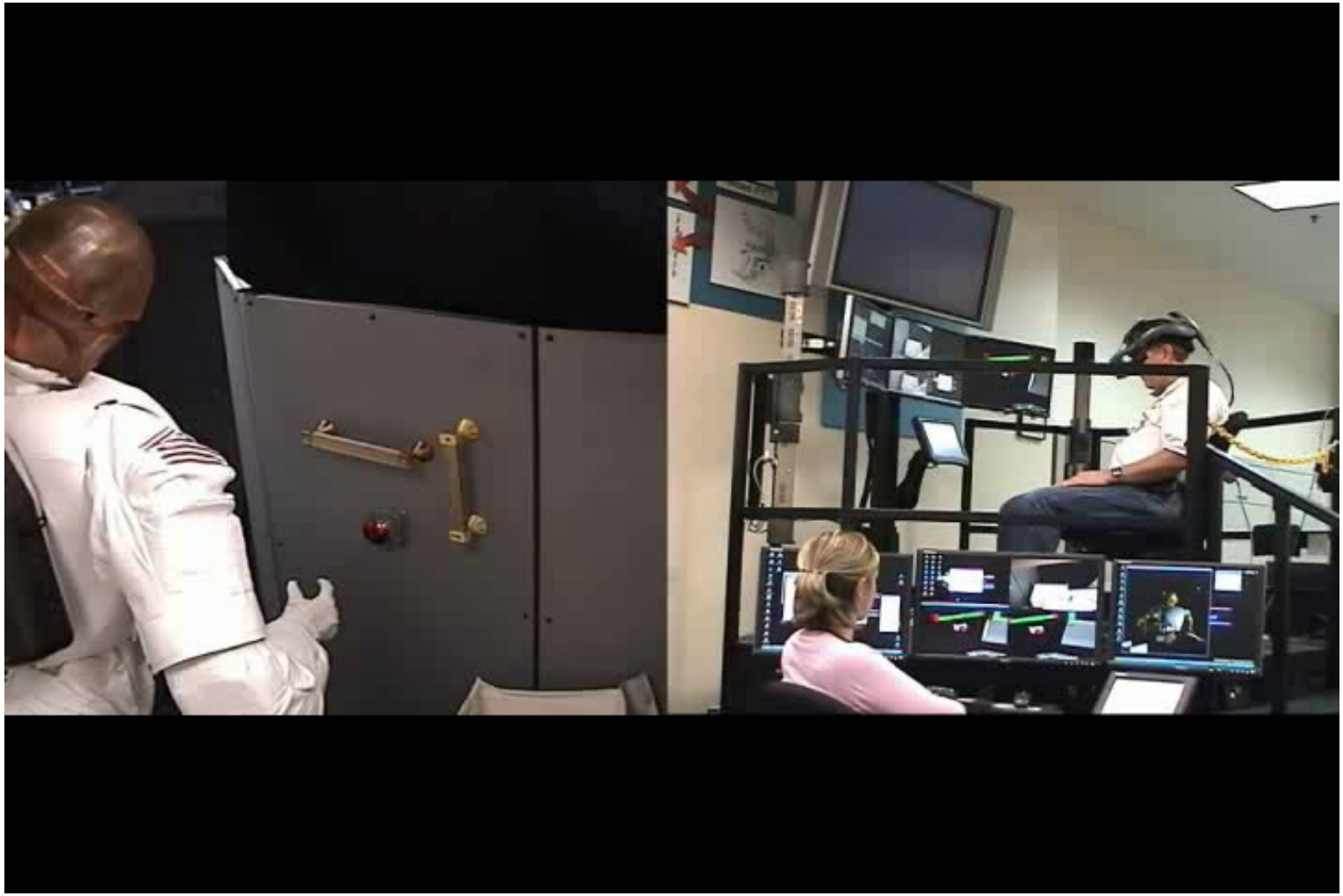






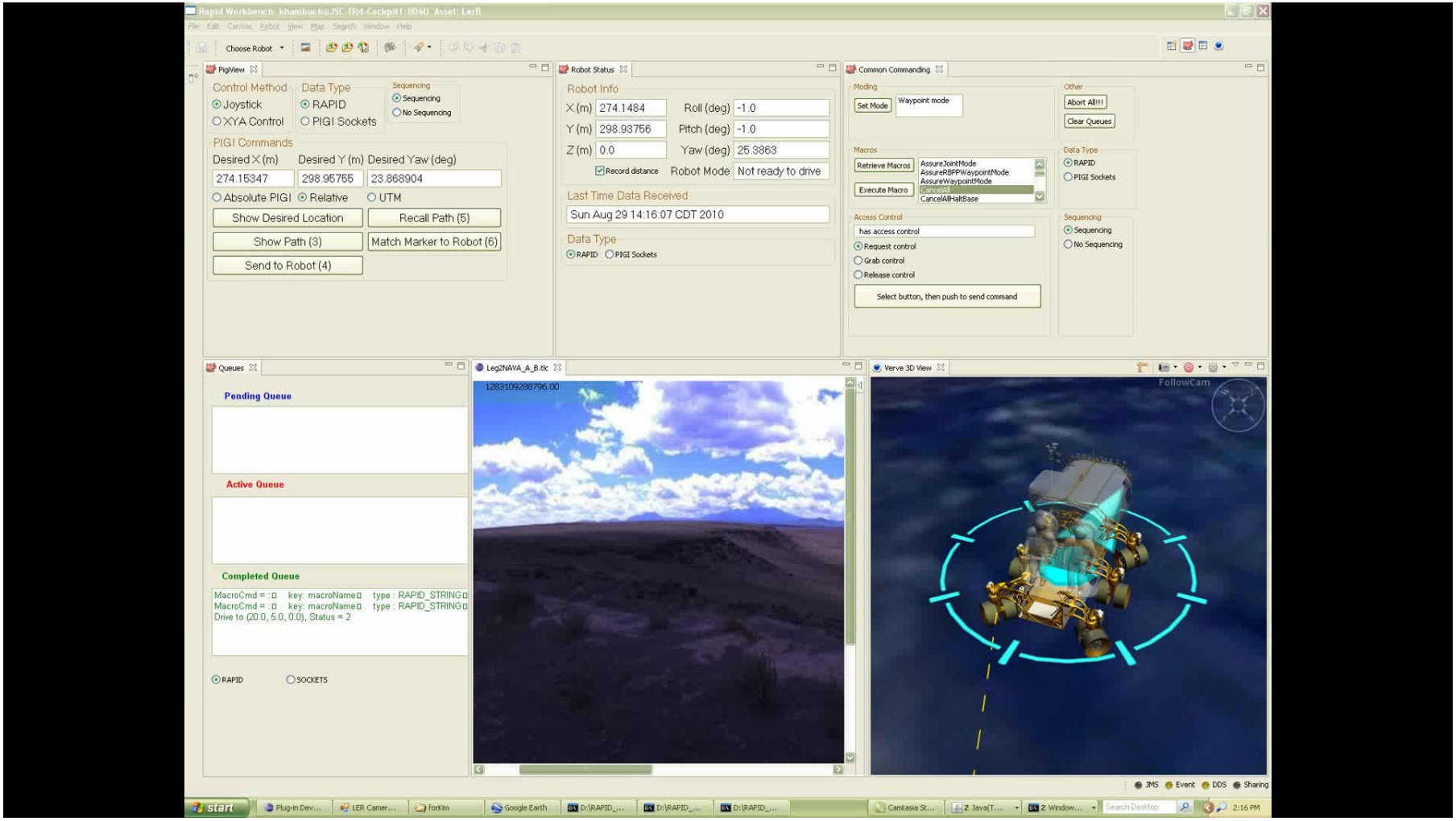


Robonaut 1 – Intent Prediction



Hambuchen, K., Bluethmann, W., Goza, M., Ambrose, R., Rabe, K., & Allan, M. (2006, December). Supervising remote humanoids across intermediate time delay. In *2006 6th IEEE-RAS International Conference on Humanoid Robots* (pp. 246-251). IEEE.

Space Exploration Vehicle – Predictive Interactive Graphical Interface (PIGI)



Burridge, Robert R., and Kimberly A. Hambuchen. "Using prediction to enhance remote robot supervision across time delay." *2009 IEEE/RSJ International Conference on Intelligent Robots and Systems*. IEEE, 2009.

Centaur 2 – Remote Sample Collection

Hambuchen, K., Burridge, R. R., Ambrose, R. O., Bluethmann, W. J., Diftler, M. A., & Radford, N. A. (2012, May). Forming human-robot teams across time and space. In *Global Space Exploration Conference* (No. JSC-CN-26347).

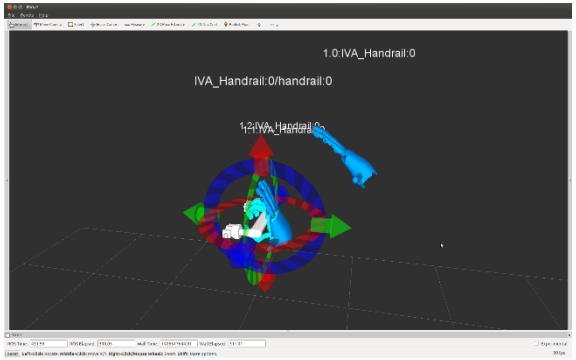
DARPA Robotics Challenge - Valkyrie

The primary technical goal of the DRC is to develop human-supervised ground robots capable of executing complex tasks in dangerous, degraded, human-engineered environments.

- 15 month design-operation
- Degraded communication
- Example set of tasks to be completed:
  - Open/close valve
  - Open & walk through door
  - Cut hole in dry wall
  - Attach fire hose to socket
  - Climb ladder

Affordance Templates

- Affordance Templates
  - Provide task-level structure for robots to execute complex tasks
  - Built upon Robot Operating System (ROS) and RViz (ROS visualization tool) – open source robotic software tools
  - Generalizable to all robot types
- Affordance Template ROS package
  - Allows for quickly programming, adjusting, and executing robotic tasks

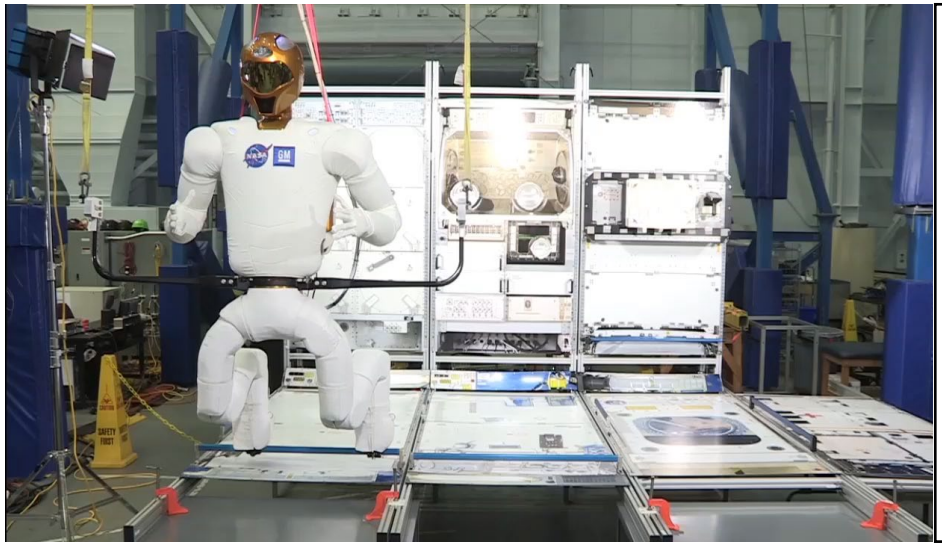


Hart, Stephen, Paul Dinh, and Kimberly A. Hambuchen. "Affordance templates for shared robot control." 2014 AAAI Fall Symposium Series. 2014. * cited by 16

Hart, Stephen, Paul Dinh, and Kimberly Hambuchen. "The affordance template ROS package for robot task programming." 2015 IEEE international conference on robotics and automation (ICRA). IEEE, 2015. * cited by 75

Affordance Templates

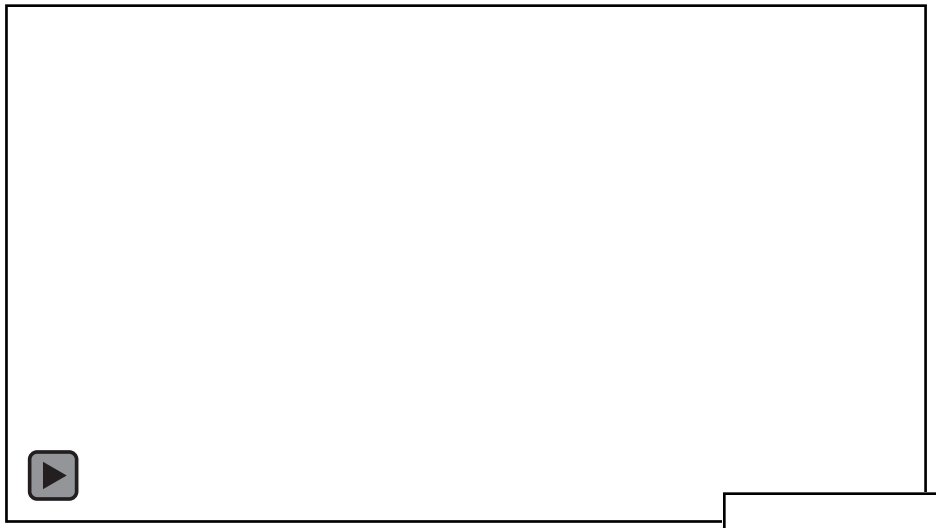
Affordance Templates – Robonaut 2



Affordance Templates – NASA Partners

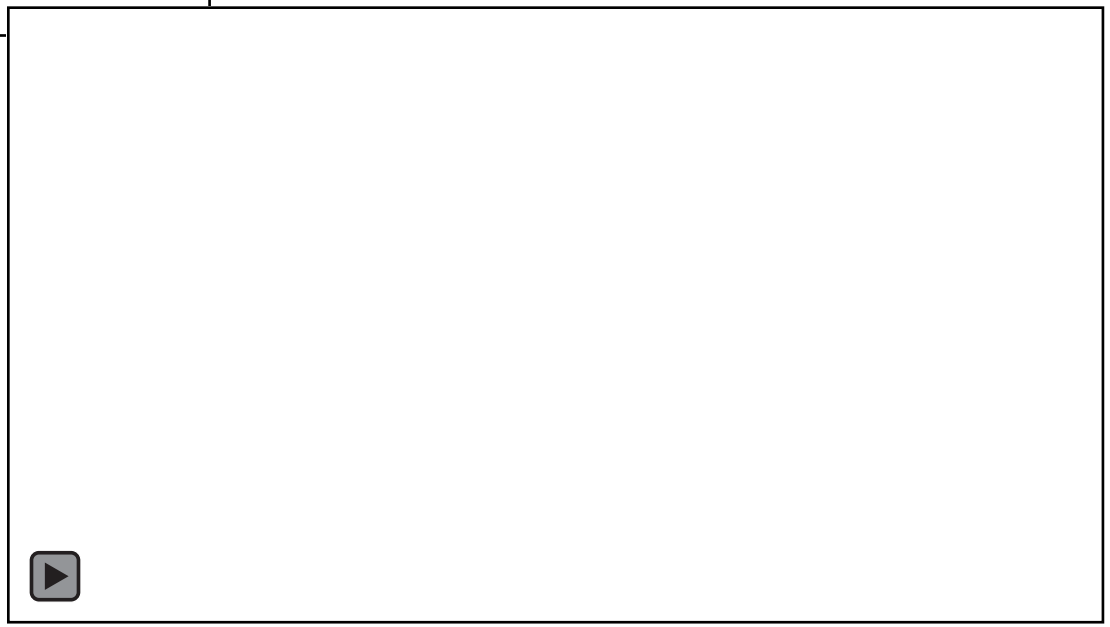
Azimi, S., Zemler, E., & Morris, R. (2019). Autonomous robotics manipulation for in-space intra-vehicle activity. In *Proceedings of the ICAPS Workshop on Planning and Robotics* (Vol. 3).

Affordance Templates – External Partners

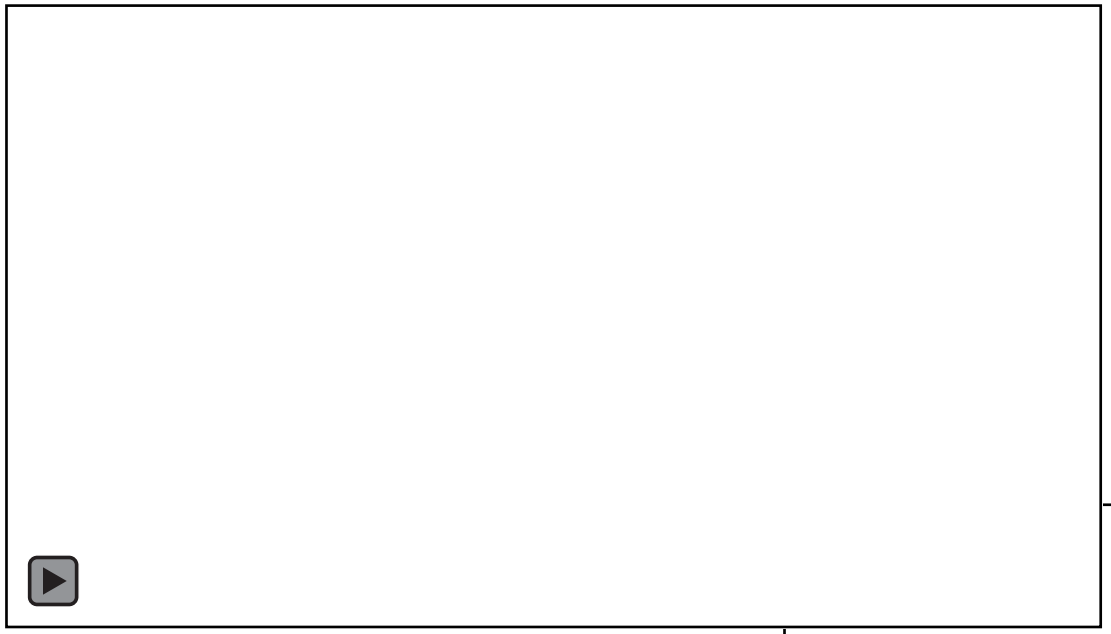


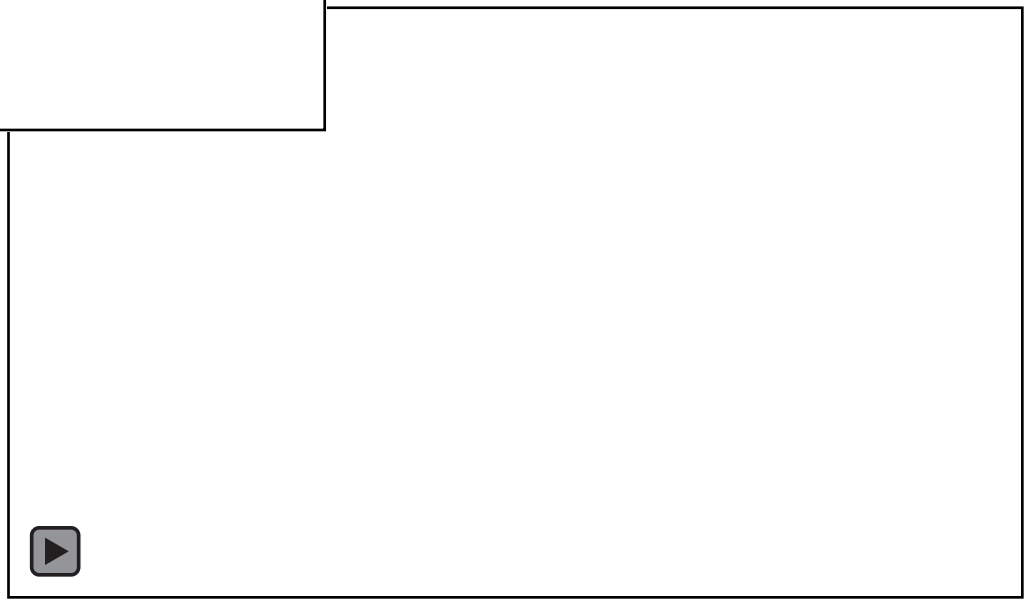
Irregular Warfare Technical Support Directorate, DoD

Woodside Energy

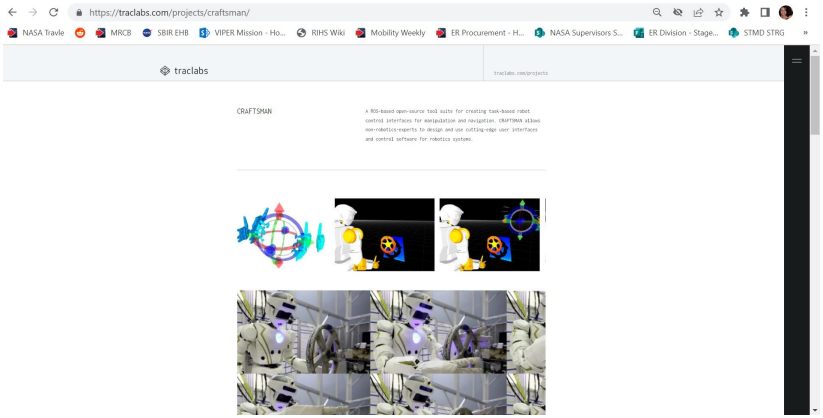


Affordance Templates – ISS Potential





Expanded Efforts



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UseIt!

Thank you!